ECOLOGY OF THE ITATIAIA RANGE, SOUTHEASTERN BRAZIL

II — CLIMATES AND ALTITUDINAL CLIMATIC ZONATION

(With 8 figures in the text)

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CONTENTS

I — INTRODUCTION

The climatic modifications that occur with the increase of altitude involve a differentiation in the vegetation. The altitudinal zonation of the climates and of the vegetation is, in certain cases, well defined, but sometimes hard to precise because of the gradual merging of one belt into another.

Descriptions of altitudinal zonation, climatic and as to vegetation are scarce for the tropics.

The region studied does not rise to a great height, but there is a true zonation, consisting of several well-delimited climatic and vegetational altitudinal belts.

The purpose of this publication is to delimit the climatic zones and describe in detail the climates of the different levels of altitude.

The data provided will serve as a basis for future studies on the behavior of the vegetation and of the several plant communities on the massif. The paper on the zones of vegetation by one of the authors (Segadas-Vianna, 1965) served as a basis for the present one.

The effects of the climates upon the vegetation at the different seasons of the year were observed by the authors during many field-trips undertaken since 1953.

The authors wish to convey special thanks to Dr. BERTHA LUTZ of the Museu Nacional for her kindness in critically reading the text and also for her valuable suggestions.

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Thanks to this direct observation of the vegetation and of the climate, it has become possible to improve and complete the interpretation of the numerical data available.

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We also extend our best thanks to the "Serviço de Meteorologia do Ministério da Agricultura", for lending us unpublished meteorological data.

The junior author is responsible for all the climatological aspects and the senior author for the vegetational ones.

II — THE REGION

GEOGRAPHICAL POSITION

The massif of Itatiaia is located in the Serra da Mantiqueira, at approximately 22° 25' S and 44° 50' W Gr. It has an area of about 1,450 km².

The Serra da Mantiqueira runs parallel to the Atlantic coast, and is separated from it by another range, also parallel, called Serra do Mar. Between these two ranges, that rise to elevations of 1,000 to 2,500 meters above sea level, lies the valley of the Paraiba river.

The massif is bordered on the south by the Paraiba valley, and on the north by the Serra Negra and the valley of the Rio Preto; towards the west, by the Rio Salto which descends from the southern part of the Serra Negra and enters the Paraiba at the village of Salto. Towards the east the limits are less easily defined, as the Itatiaia and the Pedra Selada, another great massif of the Mantiqueira, are practically continuous.

PHYSIOGRAPHY

On its southern side, that is the side facing the sea, the Massif of Itatiaia, rests on the sedimentary plain of the Paraiba river. The average elevation of this plain is 400 meters.

Physiographically, Itatiaia consists of two principal parts, the slopes and the highlands. Even though not very abrupt, the slopes are well-defined, rising on the southern, eastern and western sides, from 400 meters, and in the northern side, from 800 meters, to a mean altitude of 2,000 meters.

The *Highlands* can be subdivided into three regions: the *Aiuruoca Plain,* the *Upper* and the *Lower Highlands*. The *Aiuruoca Plain* is a large, humid and boggy plain where two rivers have their headwaters, the Aiuruoca River, which is tributary of the Paraná, and the Rio Preto, which is tributary of the Paraiba.

The *Upper Highlands* are extremely uneven and are crossed in all directions by series of rocky hills, having a chaotic and cyclopean aspect. Also there are a certain number of ridges that raise to 500 meters of altitude, such as the one in which the Agulhas Negras are localized. The surface of the *Upper Highlands,* is either covered by bogs or strewn with boulders, from 15 to 20 meters in diameter.

In this region there are also several "pozzinas", similar to those which occur in Corsega and in the Alps.

The *Lower Highlands,* on the contrary, are less uneven and its small hills, which have an altitude of less than 200 meters, have rounded profiles. The average altitude of this region is from 1,400 to 1,600 meters.

The southern slope, because of its abruptness is the one that best shows the altitudinal zonation of the vegetation.

GEOLOGY

The Massif of Itatiaia was probably formed during the Lower Jurassic. It is a massive extrusion due to the rupture of the

(*) The Ecological Survey of the Vegetation of the Federal District and State of Rio de Janeiro was proposed, in 1951, by Fernando Segadas-Vianna, through the Museu Nacional. The "Conselho Nacional de Pesquisas" sponsored it and it was begun in 1953. The research-work was organized by the proponent and carried out by GISELLE C. MACHLINE, LEDA DAU, WILMA T. ORMOND and JADIHEL LOREDO JR.

gneissic cover of a laccolith, melted by the magma. The dominant type of rock is a nephelinic syenit, compact, medium-grained and of an ash-gray color, called foyaite (LAMEGO, 1936).

The massif was probably glaciated during the Pleistocene. For more detailed information about the physiography, geology and glaciation, the reader should consult the first paper of this series (SEGADAS-VIANNA, 1965).

III — ALTITUDINAL ZONATION OF THE VEGETATION

The altitudinal zonation of the vegetation of the Massif of Itatiaia has been studied in detail by the senior author (SEGADAS-VIANNA, 1965). Three main elements have been taken into consideration for the delimitation of levels: the vegetation, the physiography and the climate.

The climate is the factor essentially responsible for the dominance of a certain type of vegetation at a certain elevation.

On the other hand, the physiography, when favorable, allows the maximum expression of vegetation according to the climatic possibilities, and, when unfavorable, causes several degrees of inhibition. The penetration of one vegetation belt into the other is generally determined and controlled by topography.

In the paper just mentioned, six belts of vegetation were recognized in regard to these three elements. They are all well delimited, and defined as follows:

Plain-Level — from 400 to 700 meters
Lower Montane-Level — from 700 to 1,100 meters
Middle Montane-Level — from 1,100 to 1,700 meters
Upper Montane-Level — from 1,700 to 2,000 meters
Highlands-Level — from 2,000 to 2,400 meters
Summits-Level — from 2,400 to 2,770 meters.

During the colonial period, the *Plain Level* was occupied by rain-forest, with a structure and floristic composition similar to the coastal rain-forest that still covers the slopes of the Serra do Mar. At the present time, all this region is covered by a secondary vegetation, composed mostly of grasses and malvaceae, which are used as pastures. In many places, the region is covered by communities of *Melinis minutiflora,* an exotic grass, which has become naturalized in Brazil and occupies extensive areas.

The upper part of this level, that is over 700 meters, is covered by a sub-climax forest, of trees that do not grow to more than 15 meters of height, and are dominated by *Tibouchina estrellensis* and *Cassia multijuga.*

The meteorological station of Rezende is located on the lower part of this level, in a situation that provides data which correspond perfectly to the climatic conditions prevailing at this level.

The second level, *Lower Montane,* has a climatic climax of rain-forest, with trees 30 to 35 meters high. However, most of this region is covered by subclimax woods with a composition and structure similar to the one that covers the upper part of the previous level. One of the characteristics of this type of forest is the presence, in the upper layer, of a great number of individuals of the palm "jussara", *Euterpe edulis.*

At certains places, for instance at Rio Bonito, there occur stretches of the climax forest that are only slightly modified.

The tree components are species of the genus *Cedrela, Cariniana, Cabralea, Nectandra,* associated with many other mesophytic species.

The Monte Serrat meteorological station, at the lower part of this level, has an inappropriate location as it is completely surrounded by the woods. Many of the data recorded do not correspond exactly to the climate that really predominates at this level, because the different elements of the weather are directly influenced by the vicinity of the forest. Thus some of them probably do not express true conditions, as for instance in relation to lightning, fog, haze and dew (see Table 6).

The third level, *Middle Montane,* has a topography more abrupt than the one of the previous level and is covered by open forest, with well-developed undergrowth and trees that attain a maximum height of 20 to 30 meters.

This forest is characterized not only by the absence of certain species that occur on the lower levels but also by the abundance of individuals of those that are present.

The lower strata are occupied by small trees of the genera: *Roupala, Drymis* and *Weinmannia.* Tree-ferns, 6 meters high, are quite common, usually forming crowded colonies. Another important characteristic is the abundance of mosses that cover the exposed places, the forest floor and the trunks and branches of the trees.

The fourth level, *Upper Montane,* is still less abrupt than the previous levels, gradually passing into the *Highlands.*

The climax vegetation is a low and very open forest. The trees branch near the ground and never reach more than 20 meters of height, and their crowns are characteristically hemispheric. The dominants are species of the genus *Cabralea.* Epiphytic bromeliads and mosses are quite abundant on the upper branches of the trees. Lianas are almost absent. The shrub layer is very dense and dominated by species of *Drymis, Leandra* and *Psychotria.* The herbaceous layer is almost absent and very poor in species.

The open places are commonly occupied by large colonies of tree-ferns with low trunks. The most frequent species are *Dicksonia sellowiana, Alsophila elegans* and *Hemitelia capensis.*

Most of the area of this level is covered by a subclimax forest dominated by *Croton* associated with *Weinmannia, Cabralea* and *Drymis.*

Other important communities are the ones

Unfortunately these two levels have no permanent meteorological stations, nor are there any occasional observations of the characteristics of the climate available.

The fifth level, *Highlands,* situated within the altitudes of 2,000 and 2,400 meters differs from the previous levels, not only by the aspect of the vegetation, but also as to topography.

The vegetation can be grouped into three main types: woods, grasslands and bogs.

The forests are of a dwarf type. The trees, ramifying near the ground, have an average of from 5 to 6 meters of height, sometimes reaching 10 meters. The branches are completely covered by masses of mosses and lichens and, occasionally by bromeliads. *Tillandsia geminiflora* var. *incana* is the most common species.

These forests are only found in valleys which are protected, and well-drained and have an even topography.

A great part of the *Highlands* area is dominated by shrubs such as *Senecio, Vernonia* and *Tibouchina organensis* var. *silvestris.*

covered by a vegetation of the steppe type, which is composed of several communities, corresponding to various successional stages or to several habitats not related to each other.

The plains with a bad drainage, but without a substratum of peat, are covered by a dense graminoid community, one to two meters high, dominated by *Cortaderia modesta.*

The well drained hillsides with a slight slope are covered by a community dominated by a dwarf bamboo — *Chusquea pinifolia* — that can reach two meters of height.

The well-drained plains and the ground with a slight slope are covered by a vegetation with a physiognomy and structure very similar to those of a steppe.

The main components are species belonging to the genera: *Danthonia, Deschampsia, Briza, Panicum, Andropogon, Festuca, Bromus, Trachypogon,* etc.

The much inclined hillsides are frequently occupied by two communities. One is dominated by *Baccharis discolor* and the other by *Baccharis platypoda,* both with a ground layer of grasses.

The gullies on clayish ground are covered by communities dominated by species of the genera: *Chaetostoma, Paepalanthus, Siphocampylus, Esterhazya,* etc.

The hydroseral stages are very numerous. The zonation around the "pozzinas" is well differentiated.

The bogs are of a graminoid type. The ground layer is covered by a continuous carpet of *Sphagnum,* and the upper layer is dominated by *Cladium ensifolium.*

The Alto do Itatiaia meteorological station, situated 2,199 meters above sea-level, is located on the top of a small hill near the southern edge of the plateau. The data given by this station characterize the climate of this level well. The station would however have been better located, if in the middle of the plateau instead of near one of its edges.

The sixth level, *Summits,* situated within the altitudes of 2,400 and 2,700 meters, has an extremely abrupt topography and comprises the rocky ranges and the high peaks that cross the *Highlands* in all directions.

The vegetation of this level is subject

to very severe conditions of wind, drainage, temperature, etc.

Chusquea pinifolia less than one meter high, occurs in dense stands, mainly in the pockets containing humus and in the well protected cornices. The valleys located between the highest peaks, full of boulders of all sizes, are occupied by many herbaceous and woody plants such as: *Purpurella hospita, Fuchsia campos-portoi, Oxalis calva, Zygocactus obtusangulus* and *Griselina ruscifolia.*

IV — CLIMATIC ELEMENTS

GENERAL CONSIDERATIONS

The existence of three meteorological stations and of a pluviometric station have enabled us to correlate accurate weather data with the vegetation zones. These stations have accumulated a considerable amount of information through the years, which it has been impossible to publish, so far, except for the means.

We have brought together in Table 3 all the significant figures for the Itatiaia area and neighbouring highlands available to us.

The data for Rio de Janeiro will permit comparison with a sea-level climate at the same latitude. Resende is on the banks of the Paraiba River at a mere 430 meters, Monte Serrat, at the foot-hills of Itatiaia, is about twice as high, although only a few kilometers away. Unfortunately, there is no station on the mountain itself between 816 and 2,199 meters (and therefore none within the 1,100-1,700 meters level). The neighbouring Campos do Jordão, however lie at 1,630 meters, and the Campos da Bocaina, on the Serra do Mar, at 1,480 meters. Alto do Itatiaia is at 2,199 meters and Agulhas Negras at 2,450 meters.

The record is not absolutely complete. The most regrettable gap is the lack of temperature data for the highest altitude.

Table 1 indicates the geographic position, coordinates and altitude and Table 2 gives information about the source of the data and the periods of observation of the different weather elements.

STATION	STATE	ALTITUDE	LATITUDE	LONGITUDE
REZENDE	RIO DE JANEIRO	410 m	22° 29' S	44° 28' W.G.
MONTE SERRAT	RIO DE JANEIRO	816 m	22° 27' S	44° 50' W.G.
ALTO DO ITATIAIA	RIO DE JANEIRO	2.199 m	22° 25' S	44° 50' W.G.
BASE DAS AGULHAS NEGRAS	RIO DE JANEIRO	2.450 m	22° 24' S	44° 50' W.G.
ALTO DA BOCAINA	SÃO PAULO	1.480 m	22° 43' S	44° 31' W.G.
CAMPOS DO JORDÃO	SÃO PAULO	1.630 m	22° 44' S	45° 34' W.G.
PETROPOLIS	RIO DE JANEIRO	847 m	22° 31' S	43° 11' W.G.
RIO DE JANEIRO	FEDERAL DIST.	44 m	22° 54' S	43° 10' W.G.

Table 1 — Geographic location of the meteorological stations.

The annual regime of the different weather elements are analyzed briefly.

In the "Normais" published by the "Serviço de Meteorologia" (ANONYMOUS, 1941) there is an inversion of the pluviometric values for the Alto Itatiaia Station (pg. 41)

for the months of January and February. The value 399.3 mm corresponds to the month of January and not to February.

TEMPERATURE (Figs. 1, 8; Tabs. 3, 4, 5)

The climate of the *Plain Level* has an annual mean temperature of 20.7°C. This mean results from 31 years of observation (Table 2).

The coldest months of the year are June, July and August, with and average of 17.4°C, and the months of January, February and March are the hottest, with an average of 23.5°C.

The summer (December to February) has an average of 23.3°C. The difference between the mean temperature of summer and winter is of 5.9°C.

The winter amplitude is of 1.4°C and that of the summer of 0.9°C.

The hottest month is February with 23.7°C, and the coldest July, with 16.8°C which gives an amplitude of 6.9°C. The absolute minimum temperature for July was 0°C, recorded on July 18, 1926, and the maximum on February was 37.4°C, recorded on February 4, 1933.

The mean of the maxima, during the 31 years of observation, is 27.6°C and the mean of the minima is 15.9°C. In that observation period, the absolute maximum recorded was 38.4°C, which occurred on the 8th and 9th December, 1940, and the absolute minimum was of minus 0.3°C recorded on July 26, 1918. Figure 1 shows the annual behaviour of the maxima and of the minima and Table 4 gives the absolute maxima and minima recorded for every month of the observation period.

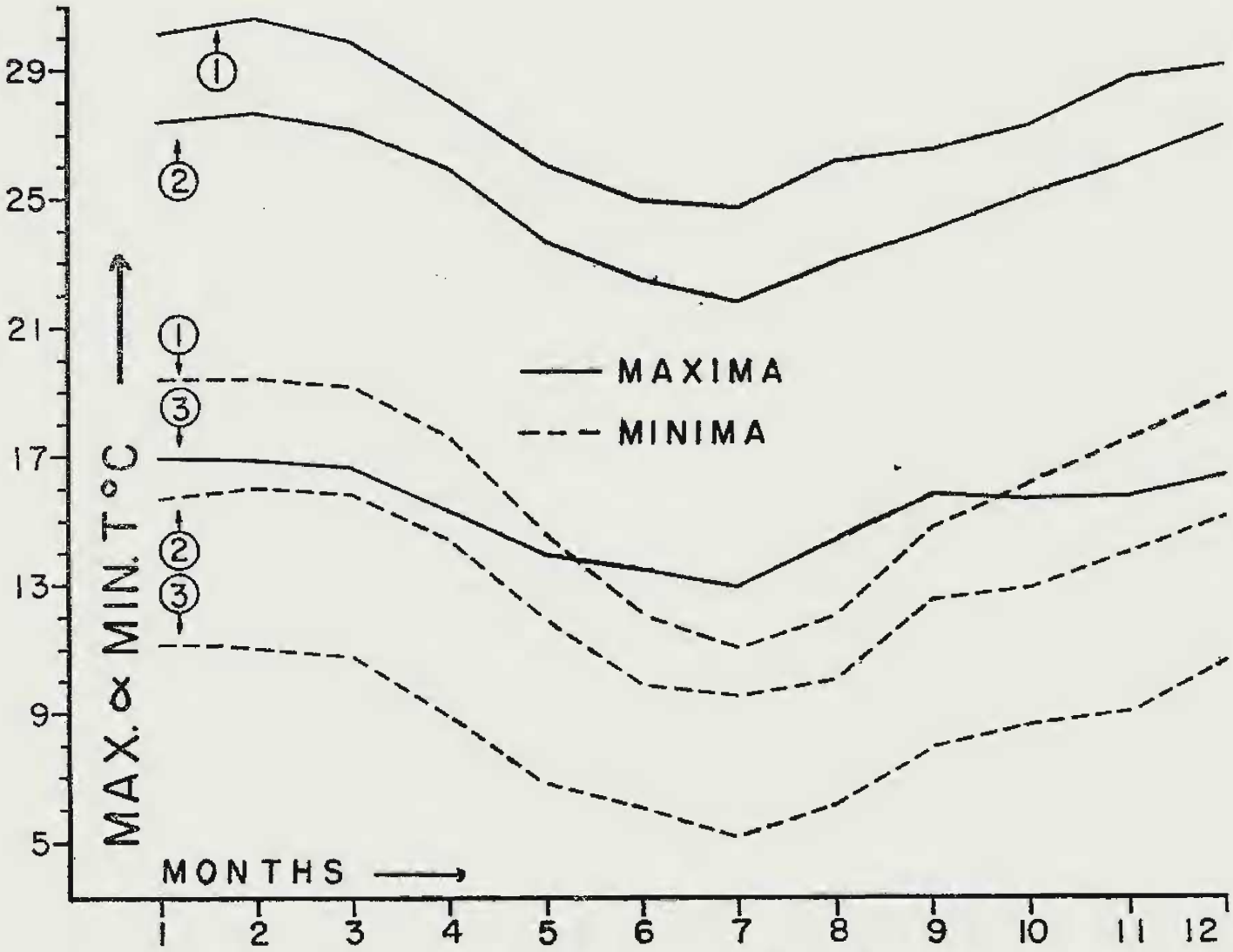

Figure 1 — Monthly average **maximum** and **minimum temperature** (1 = Plain Level; 2 = Lower Montane Level; 3 = Highlands Level).

The climate of the *Lower Montane Level*

S T A T I O N	E L E M E N T	S O U R C E	PERIOD
REZENDE	TEMPERATURE	SERV. METEOROLOGIA	1911-1942
	RAINFALL	SERV. METEOROLOGIA	1911-1942
	Nº RAINY DAYS	ANONYMOUS - 1941	1911-1935
	REL. HUMIDITY	ANONYMOUS - 1941	1911-1942
	EVAPORATION	ANONYMOUS - 1941	1911-1942
	INSOLATION	ANONYMOUS - 1941	1911-1942
	CLOUDINESS	ANONYMOUS - 1941	1911-1942
	OTHER FENOMENA	ANONYMOUS - 1941	1916-1942
MONTE SERRAT	TEMPERATURE	SERV. METEOROLOGIA	1916-1933
	RAINFALL	SERV. METEOROLOGIA	1916-1933
	Nº RAINY DAYS	ANONYMOUS - 1941	1911-1935
	REL. HUMIDITY	ANONYMOUS - 1941	1916-1933
	EVAPORATION	ANONYMOUS - 1941	1916-1933
	INSOLATION	ANONYMOUS - 1941	1916-1933
	CLOUDINESS	ANONYMOUS - 1941	1916-1933
	OTHER FENOMENA	ANONYMOUS - 1941	1916-1933
ALTO DO ITATIAIA	TEMPERATURE	SERV. METEOROLOGIA	1916-1940
	RAINFALL	SERV. METEOROLOGIA	1916-1940
	Nº. RAINY DAYS	SERV. METEOROLOGIA	1916-1940
	REL. HUMIDITY	SERV. METEOROLOGIA	1916-1940
	EVAPORATION	SERV. METEOROLOGIA	1916-1940
	INSOLATION	SERV. METEOROLOGIA	1916-1940
	CLOUDINESS	SERV. METEOROLOGIA	1916-1940
	OTHER FENOMENA	SERV. METEOROLOGIA	1916-1940
BASE DAS AGULHAS NEGRAS	RAINFALL	TORRES & MORTERA - 1948	1914-1938
ALTO DA BOCAINA	TEMPERATURE	SETZER - 1946	1914-1919
	RAINFALL	SETZER - 1946	1914-1919
CAMPOS DO JORDÃO	TEMPERATURE	SETZER - 1946	1906-1941
	RAINFALL	SETZER - 1946	1906-1944
PETRÓPOLIS	TEMPERATURE	SETZER - 1946	1913-1930
	RAINFALL	SETZER - 1946	1913-1930
RIO DE JANEIRO	TEMPERATURE	ANONYMOUS - 1941	1890-1938
	RAINFALL	ANONYMOUS - 1941	1890-1938

Table 2 — Source and periods of observation of the different climatic elements.

has a mean temperature of 18.2°C, and an annual amplitude of 6.6°C, according to an observation period of 17 years (Table 2).

As at the previous level, the warm season embraces the months of December, January and February and has a mean of 20.8°C. The amplitude is 0.5°C; the hottest months are January and February, both with an average of 21.0°C. Both, March and December, have the same mean temperature, a fact that allows us to consider the summer (warm season) as embracing four months (December to March). Adopting this criterium, we should consider the summer of the previous level as also having a duration of four months, since the difference between the means of March and December is only 0.4°C.

The mean of the maxima, for a 17 years period, is 25.0°C; figure 1 shows the annual behaviour of the recorded maxima. The absolute maximum observed until 1933 was 35.3°C, recorded on November 8, 1919.

The absolute maximum observed during the two hottest months, January and February, was 34.6°C, recorded on January 31, 1933. The absolute maxima for the various months are given in Table 4.

The cold season, including the months of June, July and August, has a mean of 15.1°C. The amplitude of variation is 1.4°C, and the coldest month is July with 14.4°C for mean. The absolute minimum for this month was 0°C, recorded on July 15, 1932, this is also the absolute minimum recorded until 1933.

The mean of the minima recorded during 17 years is of 13°C, so that the difference between the means of the maxima and those of the minima is 12°C.

The *Highlands Level* has an annual mean temperature of 14.4°C, that corresponds to a 20 years observation period (Table 2).

The summer (December to February) has a mean of 13.4°C. The amplitude is 0.5°C; the month of January, the hottest one, has a mean of 13.6°C. The months of March and December have the same mean temperature, 13.1°C, so we may consider the warm season as having a duration of four months (December to March).

The absolute maximum in 20 years was 23.1°C, recorded on September 27, 1916, while the absolute maximum of the hottest month was 20.9°C, recorded on January 9, 1925. The mean of the maxima recorded until 1940 is 15.2°C.

Analysing figure 1 we see that the curve for the maxima of this level can almost be superimposed on the curve for the minima of the *Plain Level.* During the hottest months the maxima for this level are lower than the minima of the *Plain Level.* There is a gap between the curves corresponding to the maxima of the *Plain, Lower Montane* and *Highlands Levels.* This does not occur in the curves of the minima.

The winter (June to August) has a mean temperature of 9°C., July being the coldest month, with a mean of 8.4°C. The amplitude of variation during the winter is 1.3°C.

The absolute minimum recorded on the coldest month (July), minus 6°C, recorded on July 11, 1918, is also the absolute minimum recorded until 1940, that is, during 20 years. The mean of the minima is 8.4°C; the difference between the means of the maxima and minima is 6.8°C, and the annual amplitude 5.2°C.

PRECIPITATION (Figs. 2, 3, 8; Tabs. 3, 5)

The *Plain Level* has an annual mean precipitation of 1589.7 mm, corresponding to an average of 153 rainy days per year, or 42% of the days of the year.

The rainiest month is January, with a mean of 270.9 mm, and the least rainy is July with 22.7 mm.

The rainy season goes from December to February, totalizing, on an average, 782.2 mm, which correspond to 50% of the annual rainfall. During this season the average number of rainy days is 20. The month of January has an average of 22 rainy days. The maximum daily precipitation recorded until 1942 was 140.0 mm, on December 11, 1926.

The dry season, which coincides with the winter, includes the months of June, July and August and has an average total of 77.1 mm, that corresponds to only 4.8% of the annual total. This precipitation falls on only 19 days. The months of July and August have, on an average, only 8 rainy days.

The *Lower Montane Level* has an annual mean precipitation of 1699.0 mm, falling on an average of 116 days, or in other words, 31,5% of the days of the year.

In the same way as on the previous level, here also the rainiest month is January, with

STATION	REZENDE		MONTE SERRAT		ALTO DO ITATIAIA		BASE DAS AGULHAS NEGRAS		ALTO DA BOCAINA		CAMPOS DO JORDEO		PETROPOLIS		RIO DE JANEIRO	
ELEMENT	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm	Temp. °C	Rf. mm
JAN.	23.6	270.9	21.0	289.2	13.6	404.2	NO AVAILABLE DATA	416.6	16.2	281.0	16.3	285.0	21.0	309.0	25.1	127.1
FEB.	23.7	254.5	21.0	249.8	13.5	357.6		353.5	191.0	293.0	16.4	236.0	20.9	253.0	25.4	118.2
MAR.	23.2	211.2	20.5	227.6	13.1	314.6		294.2	15.3	193.0	15.5	185.0	20.1	303.0	24.9	129.6
APR.	21.7	102.1	19.1	110.7	11.5	152.2		154.5	13.8	127.0	13.7	81.0	18.4	160.0	23.4	91.8
MAY	19.2	39.6	16.6	48.3	9.7	74.6		66.9	11.5	48.0	10.6	50.0	16.2	101.0	21.8	66.7
JUN.	17.4	25.0	15.1	31.5	8.9	44.4		34.4	10.8	56.0	9.6	48.0	15.3	68.0	20.8	58.1
JUL.	16.8	22.7	14.4	33.5	8.4	38.4		29.2	10.4	24.0	8.5	42.0	14.4	61.0	20.1	43.2
AUG.	18.2	29.4	15.8	37.0	9.7	54.8		40.3	10.7	30.0	9.8	44.0	15.3	71.0	20.6	41.8
SEPT.	19.7	59.9	17.4	71.6	11.4	100.2		81.3	13.6	52.0	12.3	81.0	17.0	101.0	20.9	64.8
OCT.	20.6	127.7	18.2	134.9	11.8	196.8		174.2	14.1	147.0	13.8	154.0	17.3	183.0	21.5	85.2
NOV.	22.0	189.9	19.3	185.6	12.1	271.4		256.7	14.9	174.0	15.1	190.0	18.8	265.0	22.8	93.5
DEC.	22.8	256.8	20.5	279.3	13.1	385.5		371.3	15.4	256.0	15.8	275.0	19.6	303.0	24.5	128.6
YEAR	20.7	1589.7	18.2	1699.0	14.4	2407.6		2273.1	13.6	1681	13.1	1671	17.85	2178.0	22.7	1048.6

Table 3 — **Temperature** and **rainfall** for the Itatiaia area and neighbouring highlands.

STATION	ABSOLUTE MAXIMUM						ABSOLUTE MINIMUM					
	REZENDE		M. SERRAT		A. ITATIAIA		REZENDE		M. SERRAT		A. ITATIAIA	
	°C	DATE	°C	DATE	°C	DATE	°C	DATE	°C	DATE	°C	DATE
JAN.	37.4	6 - 31	34.6	31 - 33	20.9	9 - 25	14.3	17 - 20	7.0	27 - 28 8 - 32	3.7	24 - 25
FEB.	37.4	4 - 33	33.0	6.11.12 and 17 - 28	21.6	6 - 31	13.2	28/29 - 16	10.0	25 - 26	2.4	28 - 16
MAR.	36.5	1 - 15 5 - 39	32.6	14 - 23	20.8	1 - 15	12.4	24 - 33	9.4	7/9 - 16	3.2	2.7 - 20
APR.	35.0	9 - 40	31.6	2 - 24	20.4	6/7 - 27	8.9	24 - 17	5.8	25 - 17	0.3	26 - 32
MAY	34.5	3 - 41	30.0	1 - 32	21.3	15 - 14	3.3	23 - 20	2.2	31 - 17	- 3.0	31 - 17
JUN.	32.2	5 - 34	27.8	17/23 - 18	22.5	22 - 26	- 0.3	26 - 18	0.8	1 - 17	- 4.8	25 - 18
JUL.	31.8	26 - 40	27.6	29 - 25	20.6	29 - 25	0.0	18 - 26	0.0	15 - 32	- 6.0	11 - 18
AUG.	34.7	25 - 40	29.2	26 - 25 25 - 25	20.6	27 - 25	2.7	8 - 18	1.8	3 - 27	- 3.4	8 - 18
SEP.	37.0	27 - 16	31.2	28 - 26	23.1	27 - 16	4.5	5 - 41	3.0	12 - 18	- 3.0	26 - 20
OCT.	37.7	27 - 13	35.2	22 - 28	22.3	15 - 14	8.0	8 - 12	6.0	17/18 - 29	- 1.1	13 - 24
NOV.	37.1	8 - 34	35.3	8 - 19	21.2	3 - 24 7 - 27	9.7	9 - 21	6.4	13 - 31	- 0.3	24 - 30
DEC.	38.4	8/9 - 40	35.0	25 - 23	21.8	25 - 29	12.0	19 - 27	8.0	7 - 17	2.4	9 - 25
YEAR	38.4	9/9.XII-40	35.3	8 -XI- 19	23.1	27-IX - 16	- 0.3	26- VI - 18	0.0	15- VII- 32	- 6.0	11-VII-18

Table 4 — **Absolute maxima** and **minima** of the Itatiaia area.

	PLAIN LEVEL		LOWER MONTANE LEVEL		H I G H L A N D S LEVEL		S U M M I T S LEVEL	
	MONTHS	VALUE	MONTHS	VALUE	MONTHS	VALUE	MONTHS	VALUE
DRY SEASON	J.J.A.	77.1	J.J.A.	102.0	J.J.A.	137.6	J.J.A.	103.9
% OF THE TOTAL		4.8		6.0		5.7		4.5
WET SEASON	D.J.F.	782.2	D.J.F.	818.3	D.J.F.	1147.3	D.J.F.	1141.4
% OF THE TOTAL		50.0		50.0		50.0		52.0
COLD SEASON	J.J.A.	17.4	J.J.A.	15.1	J.J.A.	9.0	-	-
WARM SEASON	D.J.F.	23.3	D.J.F.	20.8	.J.F.	13.4	-	-

Table 5 — Synthesis of the seasons in the different altitudinal vegetational belts.

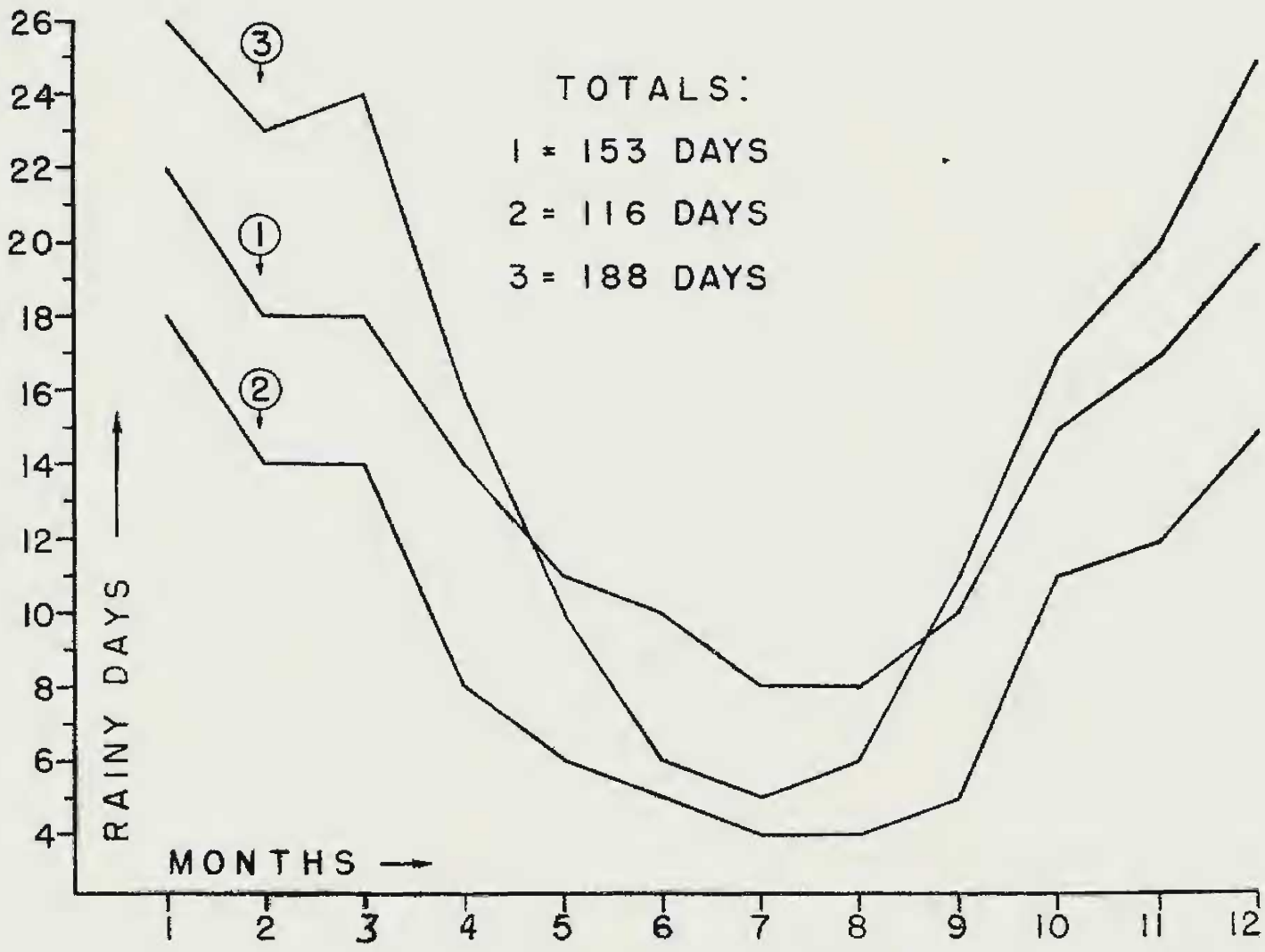

Figure 2 — Monthly average of **rainy days** (1 = Plain Level; 2 = Lower Montane Level; 3 = Highlands Level).

an average of 289.2 mm, but on the other hand the least rainy month is June with 31.5 mm.

The rainy season, from December to February, shows an average total of 818.3 mm, corresponding to 50% of the annual amount. During this season, the annual average of rainy days is 15. The month of January has an average of 18 rainy days. Thus, at this level during this month, there are four days of rain less than on the previous level and also an increase of 18.3 mm on the total amount. The maximum daily precipitation recorded until 1933, was 96.4 mm, on January 1, 1917.

The dry season, embracing the months of June, July and August, has an average amount of 102.0 mm, that is, only 6% of the annual rain. This precipitation falls on a total of 12 days. The months of July and August have an average of 4 rainy days.

On the *Highlands Level,* the average annual precipitation is 2407.6 mm that falls on a average of 188 days, that is, 51.5% of the days of the year.

The greatest precipitation at this level, 404.2 mm, that occurs on January, the least rainy month is July with 38.4 mm.

The rainy season, as on the previous levels, lasts from December to February, with a total of 1147.3 mm, corresponding to 50% of the annual total. The average number of rainy days in this season is 25. The most rainy month, January, has an average of 26 rainy days. However, the maximum recorded until 1940 occurred on December 11, 1926, with a value of 159.0 mm, that coincides with that of the maximum daily precipitation recorded for the *Plain Level.*

The dry season includes the months of June, July and August with a total of 137.6 mm, that corresponds to only 5.7% of the annual total. This precipitation falls during 17 days, that is, 4.6% of the days of the year. The driest month, July, which is also the coldest one, has an average of only 5 rainy days.

This level is the only one for which we have got recorded totals for each year separately, since 1916 until 1940. Figure 3 shows the behaviour of pluviosity and temperature during the 25 year of observation.

The years of greatest rainfall were 1919 with 2969.2 mm and 1926 with 3008.5 mm, and those with lowest rate of pluviosity are: 1928 with 1966.5 mm, 1934 with 2064.0 mm, 1939 with 2084.7 mm, 1940 with 2083.4 mm and 1920 with 2146.1 mm.

Two years after the one of the highest rate of pluviosity which was 1926 occurred the lowest annual pluviosity recorded in 25 consecutive years, that is, in 1928.

In the same manner, a year after 1919, which rates the second place in pluviosity, occured the one with the highest rate of drought (1920).

The *Summits Level* has an average annual precipitation lower than the one of the previous level, that is, 2273.1 mm, which gives a minus difference of 134.5 mm.

The rainy season, with a total of 1141.4 mm, occurs in December, January and February. The total of this season corresponds to 52% of the annual amount. January, which is the most rainy month, has 416.6 mm.

The dry season occurring on June, July and August, has a total of 103.9 mm, corresponding to 4.5% of the annual total. The driest month is July with 29.2 mm.

If one compares the rain that falls during the month of January at this level with the amounts for the same month on the other levels one comes to the conclusion that it is the month of highest rate of pluviosity for the region, inspite of its annual total being smaller that of the *Highlands Level.*

At this level, the month of July is also drier than on the two previous levels and is only surpassed by the *Plain Level.*

RELATIVE HUMIDITY (Fig. 4)

The mean relative humidity of the *Plain Level* is 79.5% — March is the month with the highest humidity, that is 82.4%, and August, the one with the lowest humidity rate, that is 74.6%.

The coldest month of the year, July, has a relative humidity of 77.8%, while in February, the hottest month, the humidity is of 81.4%. The amplitude of annual variation if 7.8%.

During the rainy and warm season the mean relative humidity is 81.2%, while during the cold season, the average is 77.5%.

The next level, *Lower Montane,* has a mean annual relative humidity of 83.5%, with an amplitude of variation of 5.2%.

As on the previous level, the month with the highest rate of humidity is March: 85.7%; August, with 80.5%, has the lowest relative

humidity. July, which is the coldest month, has a mean of 81.6%, and the two hottest months, January and February, have an average of 84.9%.

The warm and rainy season has an average of 84.4% and the cold and dry season has a humidity of 81.9%.

The *Highlands Level* has a lower mean annual relative humidity than the two previous levels, that is, 79.1%. The month with the highest rate of humidity is March, 87.1%, and the month with lowest rate is August with 67.4%.

mean humidity is 68.3%, while during the warm and rainy season the average is 86.5%.

The months of November, December, January, February, March and April have a higher relative humidity than the previous levels (Fig. 4) while during the months of May, June, July, August and September relative humidity is lower than on the *Lower Montane* and *Plain Levels.*

EVAPORATION (Fig. 5)

On the *Plain Level* total evaporation du-

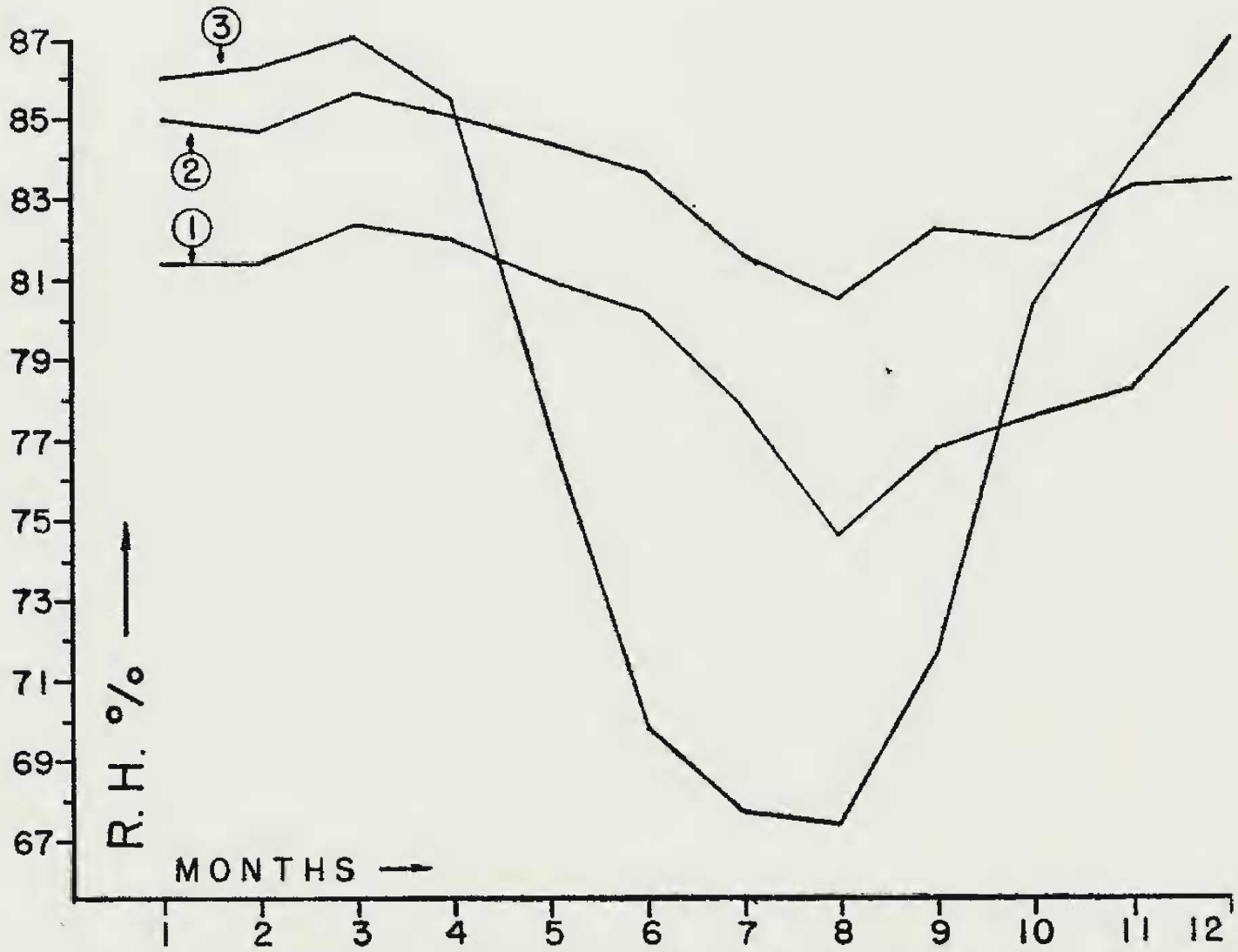

Figura 3 — **Precipitation and temperature** regime in the Highlands Level during the years 1916-1940.

During the coldest month, July, the average is 67.7%, while during January, which is the hottest month, it is of 86.0%.

The amplitude of annual variation is greater than on the previous levels, reaching 22.7%. During the cold and dry season the

ring the year, has an average of 595.7 mm, with an amplitude of variation of 21.3 mm.

The month with the highest rate of evaporation is August, 61.4 mm, and the one with the lowest rate is June, 40.1 mm.

During the warm and rainy season, De-

cember to February (782.2 mm of rain), the total evaporation is 145.5 mm. During the cold and dry season, from June to August (77.1 mm of rain), total evaporation is 149.7 mm.

During the coldest month, July, evaporation is 48.2 mm, while during the hottest month, which is February, it is 45.3 mm.

and dry season, from June to August (137.6 mm of rain), has a total of 237.2 mm.

INSOLATION (Fig. 6)

The annual amount of insolation for the *Plain Level* is in average, of 2051.1 hours.

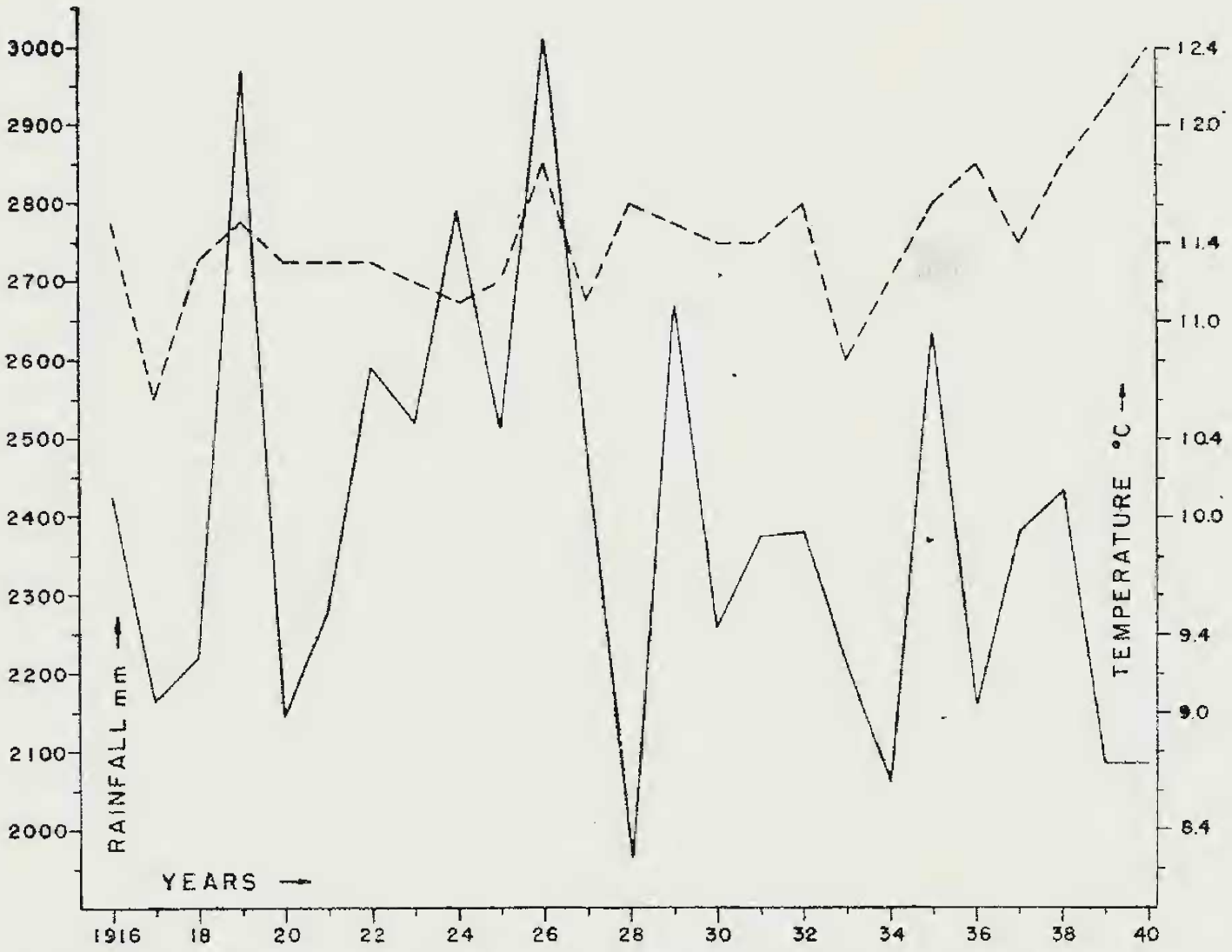

Figure 4 — Monthly average **relative humidity** (1 = Plain Level; 2 = Lower Montane Level; 3 = Highlands Level).

At the *Highlands Level* the mean annual evaporation is 660.9 mm and the amplitude of variation 51.3 mm.

The highest rate of evaporation occurs in August, with 86.5 mm, while the month of April, which is the lowest in evaporation, has an average of 35.2 mm.

The warm and rainy season, from December to February (1147.3 mm of rain), has a total evaporation of 119.6 mm, and the cold

The month of highest insolation is August with 204 hours, and the one with the lowest, is December, with 149.3 hours of insolation. Thus, the amplitude is 54.7 hours.

During the dry and cold season the amount of insolation hours is 566.4, corresponding to 60% of the total number of daylight hours, which at this latitude and this season, amounts to about 941 hours.

During the warm and rainy season, the

total of insolation hours is 482.5, corresponding to 37% of the total number of daylight hours, which for this latitude and at this season amounts to about 1297 hours.

For the *Highlands Level* the annual amount of insolation hours is on an average, 2224.5 hours; August is the month with the highest rate of insolation, i.e. 254.2 hours, and December the lowest one, with 126.1 hours. The annual amplitude is 128.1 hours.

The cold and dry season has an insolation period of 726.7 hours, corresponding to 77% of the number of hours, and the warm and rainy season an insolation period of 385.6 hours, corresponding to 30% of the summer-time daylight hours.

CLOUDINESS (Fig. 7)

Cloudiness, or else, the amount of clouds in the sky at the time of observation, is usually expressed in tenths of sky area covered by clouds. Thus, the rate of cloudiness goes from 0 to 10 and can be also computed in decimal fractions for each unit of the scale.

At the *Plain Level* the annual mean of cloudiness, that is, the average quantity of clouds, during the year is 6.7.

The cloudiest month is December with an average of 8.0, July and August are the lowest, with averages of 5.1 and 5.4 respectively.

The annual average of cloudiness on the *Lower Montane Level* is 5.4.

The months with the highest rates are December and January, both with an average of 7.0 while June and July have the lowest rates and averages of 3.7 and 3.3, respectively.

The annual average cloudiness of the *Highlands Level* is similar to the one of the *Plain Level* but its behaviour during the year

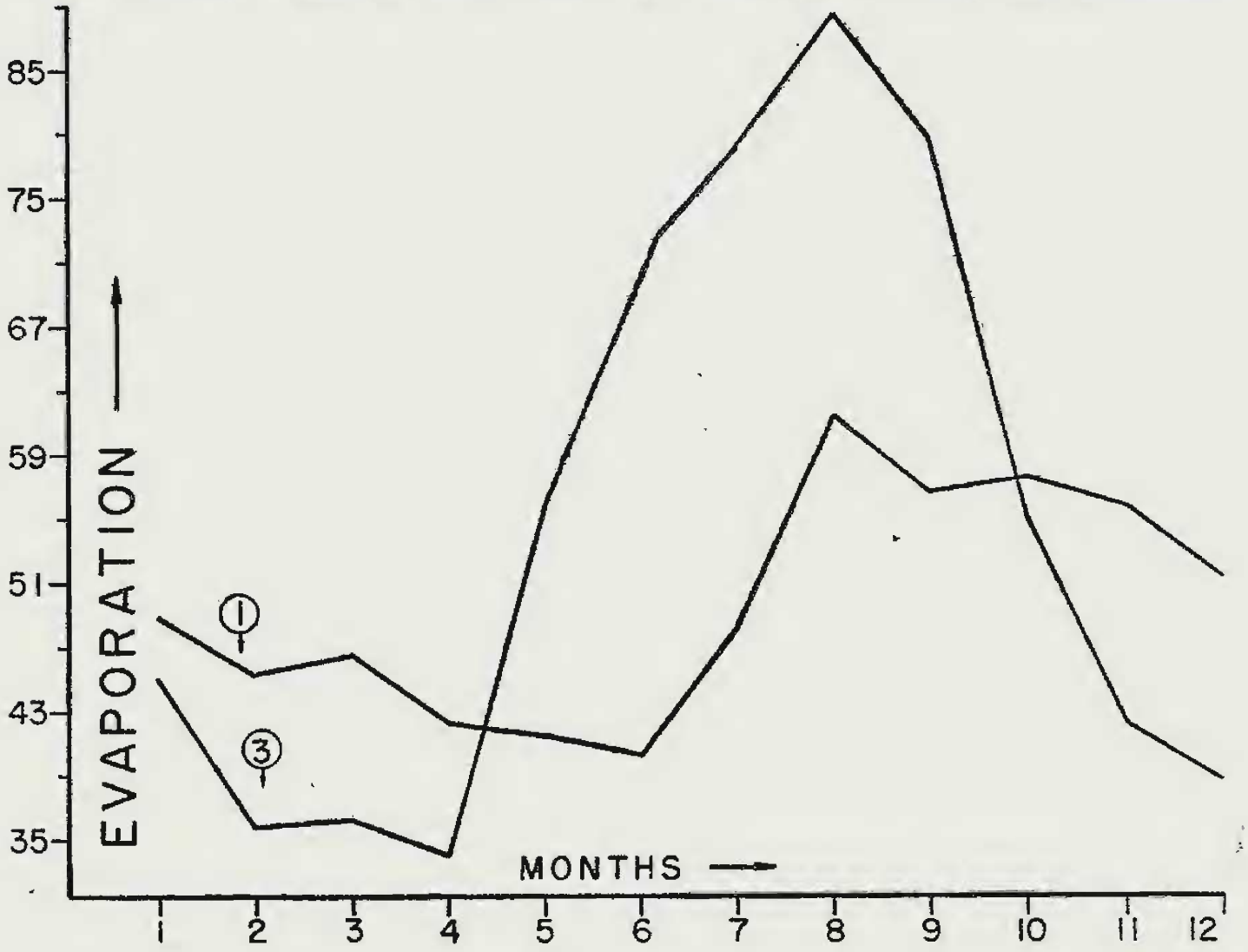

Figure 5 — Monthly average **evaporation** (1 = Plain Level; 3 = Highlands Level).

is quite different and is half-way between the one of that level and that of the *Lower Montane Level* (Fig. 7).

The month of highest rate of cloudiness is January with a mean of 8.1, and the lowest, June and July, with means of respectively 3.9 and 3.7.

The highest incidence of haze occurs in the months of August and September, respectively 11 and 14 days. From December to July haze is absent.

At the *Lower Montane Level,* where the meteorological station is surrounded by high woods, the number of foggy days during the

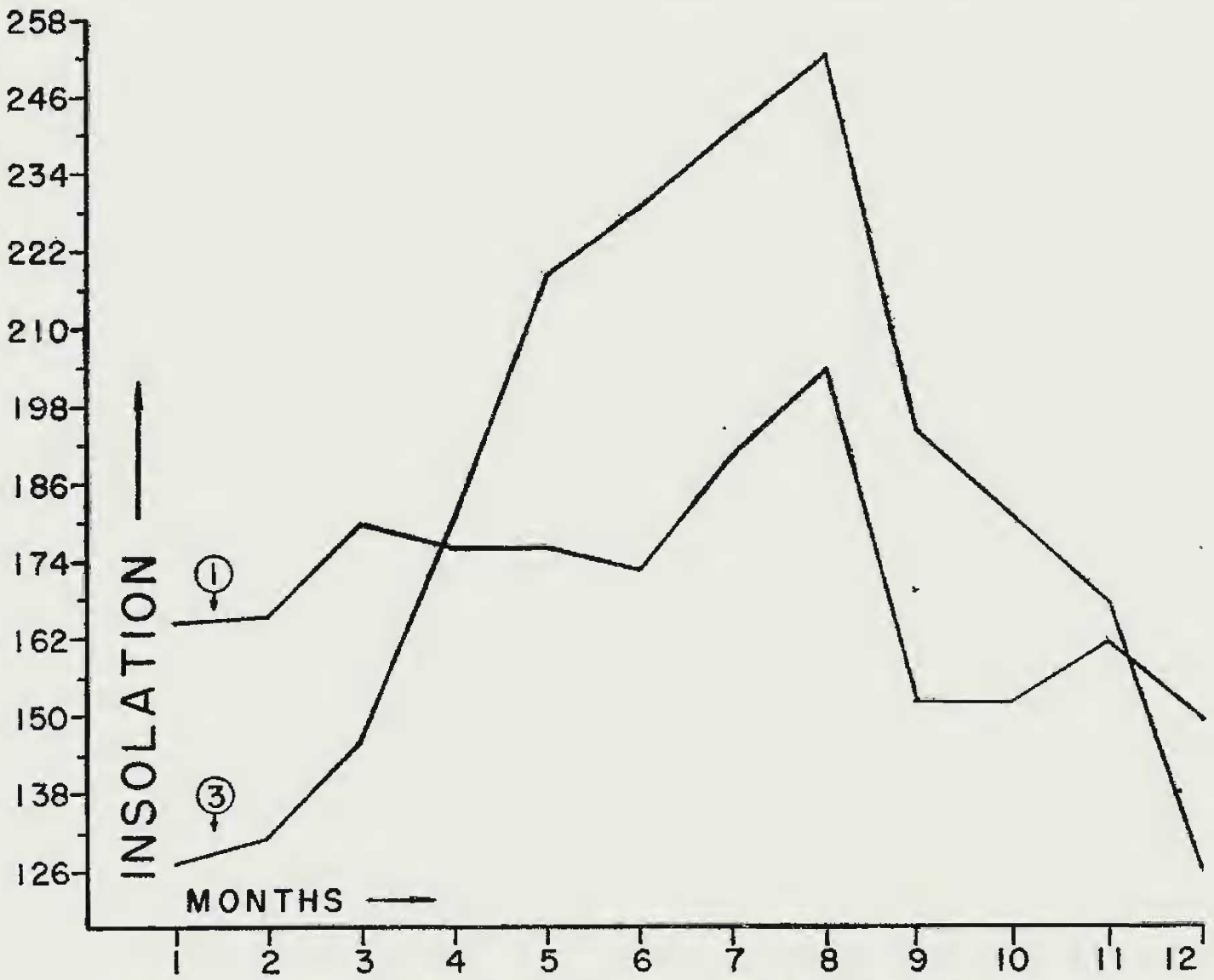

Figure 6 — Monthly average insolation (1 = Plain Level; 3 = Highlands Level).

FOG AND HAZE (Tab. 6)

Fog and haze are usually expressed by days of occurrence during the month and the year.

At the *Plain Level,* the number of days per year with fog is 103 and the number of days with haze is 33. The months with the highest incidence of fog are May, June, and July (17 days) and the ones with the lowest are October, November, December and January (1 to 4 days).

year is only 9. The months of April, June and November did not show any incidence of fog in a period of 17 years. At this level there is no recorded occurrence of haze during that observation period.

At the *Highlands Level* there are 218 foggy days during the year, that is, 59.7% of the number of days of the year. The months with highest incidence of fog are March, and October to December. The months with lowest incidence are February (9 days)

June (10 days), July (11 days) and January (11 days).

At this level the number of days with haze are only 28, which is a lower mean than the one for the *Plain Level*. The months with highest rates are August and September, are: October (18), November (18), December (21) and January (19).

At the *Lower Montane Level* there are 93 days with a blue sky during the year and 127 with overcast sky. The months with highest incidence of days with a blue sky

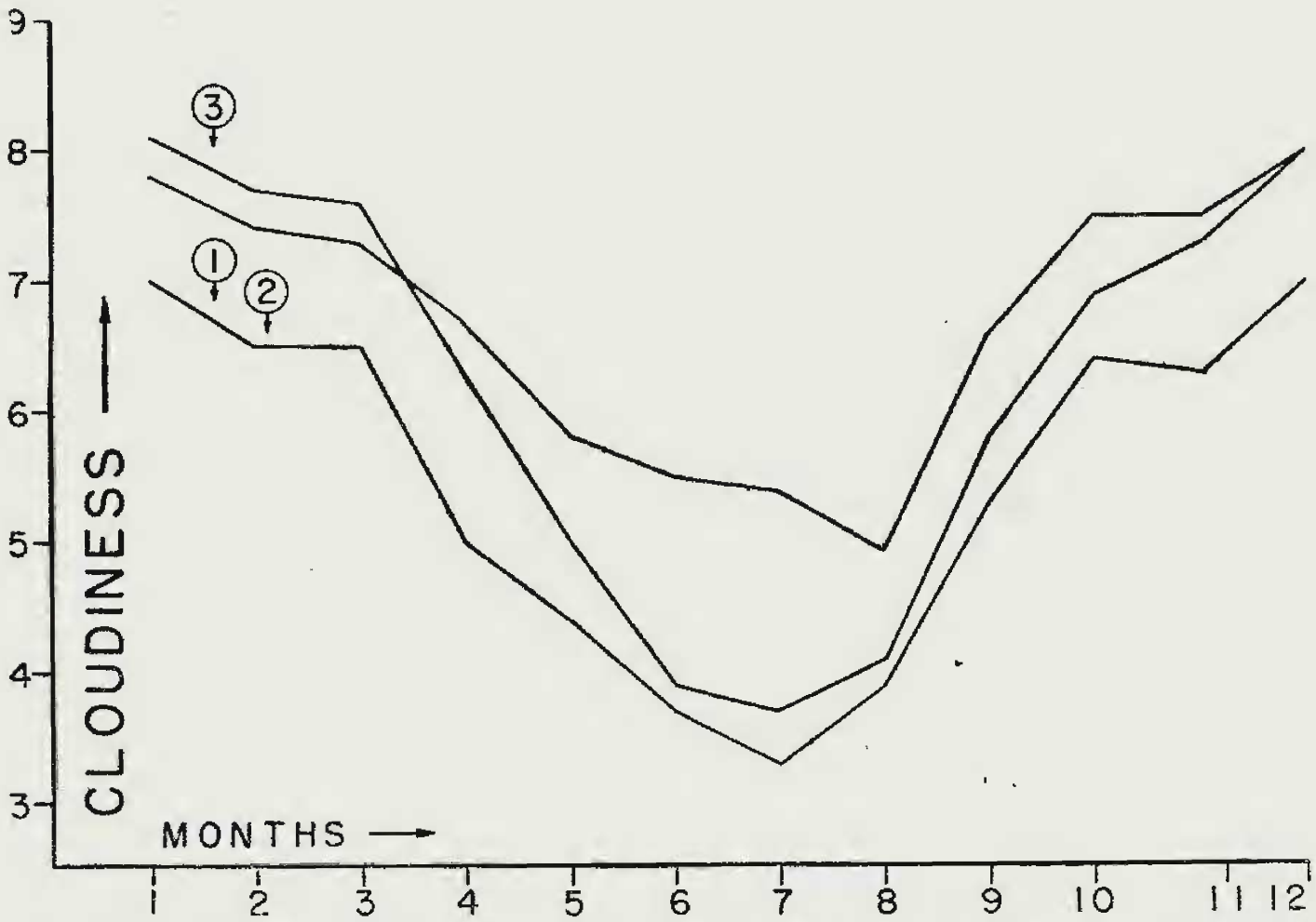

Figure 7 — Monthly average **cloudiness** (1 = Plain Level; 2 = Lower Montane Level; 3 = = Highla nds Level).

with respectively 11 and 14 days. There are seven months without incidence of haze, that is, from January to May, November and December.

BLUE AND OVERCAST SKY (Tab. 6)

At the *Plain Level*, the total number per year of days with blue sky is on an average 30, while the total number of days with overcast sky is 168.

The months with highest rate of days with a blue sky are August and September with respectively 6 and 4 days. The months with the highest incidence of overcast sky are May (11), June (14), July (16) and August (13).

At this level, during 7 months, the sky remains covered from 50% to 60% of the days of the month. The months of June, July and August have the lowest incidence of blue sky, only from 5 to 6 days.

At the *Highlands Level*, the number of days with a blue sky during the year falls to 57, while the number of overcast days rises to 148. In the months of January and February every day is overcast, while the months of June, July and August have an average of 40% of the days of the month with a clear sky. These months are also those with the lowest incidence of overcast sky days.

The months with the highest rate of days with overcast sky are December (20) and January (19).

LIGHTNING AND THUNDER (Tab. 6)

The data concerning lightning and thunder are expressed by days of occurrence and not by intensity.

August are the only months during which there is no lightning and thunder at all. The months of January, February and March have an average of 3 days per month with lightning.

These data do not give an idea of the high lightning intensity during eletric storms, which in general are of a long duration. During these storms, an intensity of about

MONTHS	FOG			HAZE			BLUE SKY			OVERCAST SKY			LIGHTNING			THUNDER			DEW			HOAR FROST			HAIL			SNOW
	R.	M.S.	A.I	R.	M.S.	A.I	R.	M.S.	A.I	R.	M.S.	A.I	R.	M.S.	A.I	R.	M.S.	A.I.	R.	M.S.	A.I	R.	M.S.	A.I	R.	M.S.	A.I	A.I.
JAN.	4	1	11	0	0	0	2	5	0	19	15	19	2	0	3	14	6	17	5	0	1	0	0	0	0	0	1	
FEB.	6	1	9	0	0	0	2	4	0	16	12	16	2	0	3	14	4	15	6	0	2	0	0	0	0	0	0	
MAR.	8	1	26	0	0	0	2	4	1	16	14	15	2	0	3	12	4	13	7	0	3	0	0	0	0	0	0	
APR.	11	0	21	0	0	0	1	8	2	13	8	10	1	0	1	5	1	6	7	1	4	0	0	2	0	0	0	
MAY	16	1	16	0	0	0	2	11	8	9	8	7	0	0	1	2	1	2	9	1	3	0	0	9	0	0	0	
JUN.	17	0	10	0	0	1	2	14	11	8	5	6	0	0	1	1	1	1	8	1	2	0	0	15	0	0	0	
JUL.	17	1	11	0	0	2	3	16	12	8	5	5	0	0	0	1	0	1	8	1	1	0	0	16	0	0	0	x
AUG.	12	1	13	11	0	10	6	13	12	8	6	6	0	0	0	2	1	1	7	0	1	0	0	10	0	0	0	
SEP.	6	1	20	14	0	10	4	8	6	14	11	12	0	0	1	4	2	4	5	0	2	0	0	3	0	0	0	x
OCT.	3	1	27	7	0	5	2	4	3	18	15	16	1	0	2	7	5	9	4	0	2	0	0	2	0	0	1	
NOV.	1	0	38	1	0	0	2	5	1	18	13	16	1	0	2	9	5	10	3	0	2	0	0	1	0	0	1	
DEC.	2	1	26	0	0	0	2	3	1	21	15	20	2	0	3	10	5	12	3	0	1	0	0	0	0	0	0	
YEAR	103	9	218	33	0	28	30	93	57	168	127	145	11	0	19	81	33	91	72	4	24	0	0	56	0	0	3	

Table 6 — Different weather phenomena for the Itatiaia area (R = Rezende; M.S. = Monte Serrat; A.I. = Alto do Itatiaia).

At the *Plain Level* the total number of days during the year with lightning is 11, and with thunder, 81.

The period from May to September is practically free from lightning and also have the lowest incidence of thunder.

The months of January, February and March are those with the highest number of days with thunder.

At the next level, *Lower Montane*, lightning has never been recorded, in spite of having an average of 33 days with thunder per year. The only month free from thunder is July, while from November to January the rate is an average of 5 to 6 days per month.

At the *Highlands Level*, the number of days per year with lightning is 19; July and 20 streaks of lightning per minute, has been observed by the authors.

The number of days with thunder reaches 91 per year, the months of December (12), January (17) and February (15) being the ones with highest incidence, and the months of June, July and August the ones with lowest incidence, having only one day with thunder per month.

DEW (Tab. 6)

At the *Plain Level*, dew falls in every month of the year, giving a total of 72 days per year, but the highest incidence occurs on May, June and July.

At the *Lower Montane Level* dew falls,

on an average, only four days per year, from April to July.

At the *Highlands Level,* the mean total number of days with dew is 24, equally distributed throughout the year.

HOARFROST, HAIL AND SNOW (Tab. 6)

At the *Plain* and *Lower Montane Levels,* hoarfrost is absent, while at the *Highlands Level* the number of days with hoarfrost during the year is of 56. It is convenient to emphasize that the occurrence of hoarfrost is only recorded on the official meteorological tables when it occurs near the meteorological station.

The occurrence of hoarfrost in the deep valleys that cross this level in all directions is far greater than the one given in the official data. This also applies to the deep cirques surrounded by rocky hills.

The months from December to March are completely free from hoarfrost. The period of highest incidence of hoarfrost corresponds to the coldest part of the year, that is, June to August. The incidence of hoarfrost at this time varies from 10 to 16 days per month.

Hail occurs only at the *Highlands Level* and only in the months of October, November and January. The annual average is 3 days.

During 25 years of weather observations only two snow falls have been recorded, both at the *Highlands Level.* These falls occurred on July 10, 1918 and September 26, 1920.

V — ALTITUDINAL CLIMATIC ZONATION

In order to give a better idea of the climatic zonation we have plotted on the same graph (see fig. 8) the temperature and the rainfall data for the three available meteorological stations and the pluviometric station.

The resulting polygons, the histograms, give a perfect idea of the altitudinal distribution and behavior of the climates that characterize each of the vegetational belts.

Analysing figure 8 we see that there is a gap between histograms number 2 and 3 that corresponds to the geometrical space that would be occupied by the histograms of the climates that characterize the *Middle Montane* and the *Upper Montane Levels* provided we had climatological data for these levels.

It can also be seen by the shape of the histograms that there are two well-marked seasons, the dry and cold season and the moist and warm season. These two seasons are well-defined above 2,000 meters, where the dry and cold season, as we shall see, is of a semi-arid type.

The positions of the histograms in relation to each other shows that rainfall increases regularly on Itatiaia from the *Plain Level* to the *Highlands Level,* but decreases somewhat above that (see Table 3). The temperature, as expected, decreases sharply with altitude.

Figure 8, as far as we know, is the best demonstration of the correlation between vegetation and climatic altitudinal zonation (see also Segadas-Vianna, 1965).

VI — CONCLUSIONS

CLIMATE OF THE PLAIN LEVEL

At this level two well marked seasons occur (fig. 8): *a warm period coincident with abundant rains and a cold period associated with a low rainfall.*

During the warm and rainy season falls fifty percent of the annual amount of rain. It lasts about three months, in spite of the duration of the warm period be of about four months. During the cold and dry season only 4.8% of the annual amount falls. At this period, relative humidity maintains itself around 77.5%.

Cloudiness is high throughout the year. Only the *Highlands Level* has, during the rainy season, a cloudiness higher than the one of this level. During 168 days the sky is overcast.

This value is the highest recorded for the massif. The same is true of the annual totals for haze and dew.

The frequency of fog is relatively high, with an incidence of 103 days per year. The same applies to thunder (81 days per year), and lightning (11 days per year).

The climate according to KOEPPEN's system (1948) is of the *Cwa* type.

CLIMATE OF THE LOWER MONTANE LEVEL

This level has also two well-marked seasons: *the warm and rainy season and the cold and dru season.*

Petropolis, at the same altitude but situated on the seaward escarpment of the Serra do Mar, has an annual amount of rain twice as higher as the one at this level.

The climate according to KOEPPEN's system (KOEPPEN, 1948) is of the *Cfb* type, that

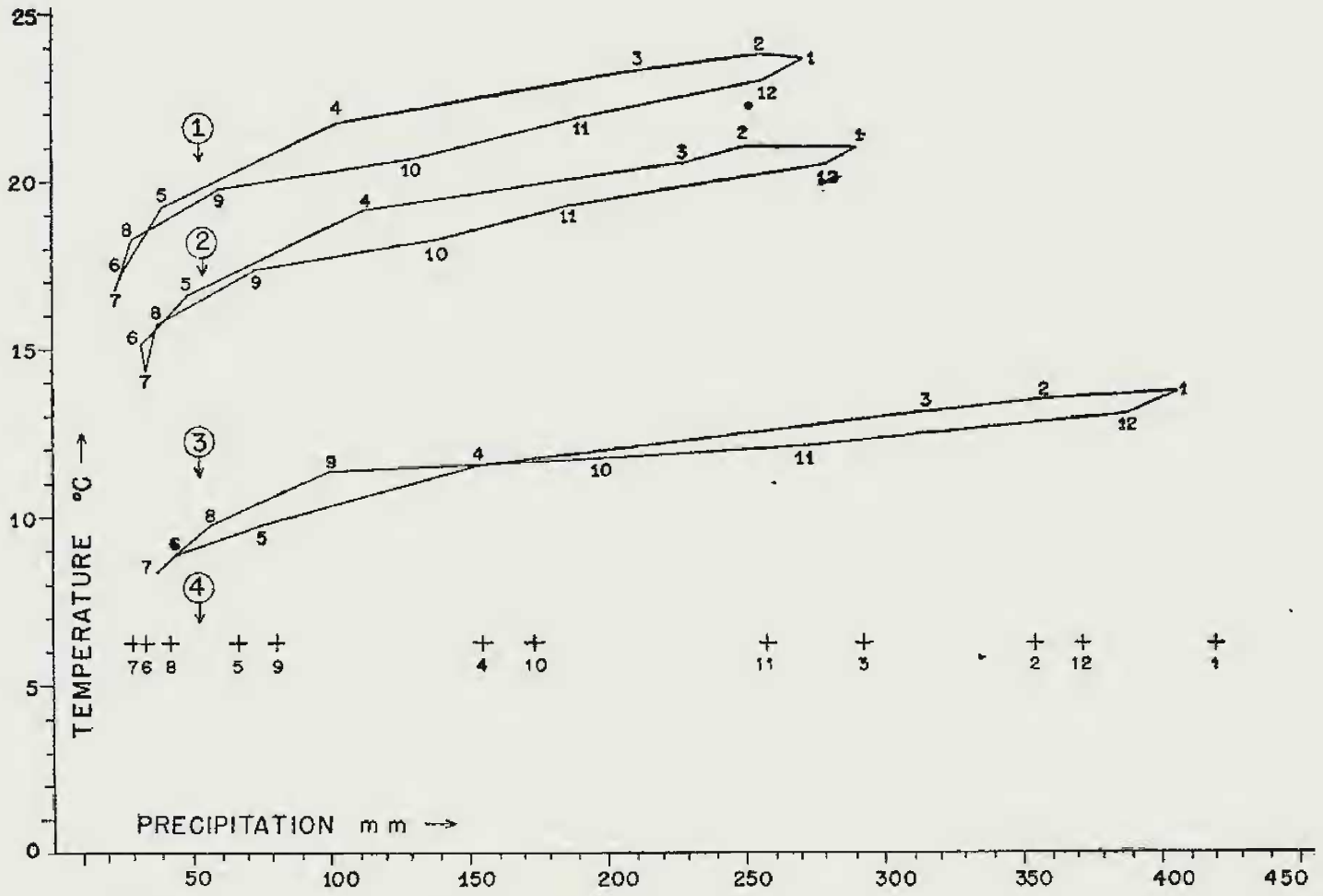

Figure 8 — Hystograms of the **climates** of the different **vegetational belts** (1 = Plain Level; 2 = Lower Montane Level; 3 = Highlands Level; 4 = Summits Level).

The warm and rainy season has a duration of about three months although the warm period of the year lasts about four months. During this season, fifty percent of the annual amount of rain falls. The cold and dry season, that goes from June to August, receives only 5% of the annual amount of rain. The relative humidity during this season is high, about 84%.

Of all the levels this is the one that has the lowest rate of cloudiness, not only at the rainy season but also during the dry season.

The absence of records for lightning and the low frequency of fog, haze and dew are undoubtedly, due to the location of the meteorological station.

is, a temperate and humid climate that allows for a climax vegetation of forest structure even under unfavourable physiographic conditions and upon undeveloped soils. Naturally, the coincidence of a dry period with a cold one determines a certain slowness on the occupation of the denuded grounds and in the recovering of the degraded vegetation.

CLIMATE OF THE MIDDLE AND UPPER MONTANE LEVELS

These two levels should have climates of the *Cfb* type because of the plant cover and of the altitudinal seriation.

The cold and dry season ought to be better individualized and more severe than on the previous levels. This should also apply to the annual amount of rainfall. The annual amplitude of variation of temperature must also be slighter at the *Upper Montane Level* than on the previous level.

CLIMATE OF THE HIGHLANDS LEVEL

At this level *the cold and dry season,* which lasts from June to August, *is so individualized that it may be considered as adverse enough to allow the establishment of a vegetation cover of a forest type.*

During this season only 5.7% the annual amount of rain falls and the average temperature is 9.0°C. The driest month, July, receives ten and a half times less rain than the rainiest month of the year.

Relative humidity remains around 67% while total evaporation reaches 237.2 mm, that is, 100 mm more than the total rainfall for this period.

This season is further characterized by the great number of insolation hours, which correspond to 77% of the total number of daylight hours.

Another adverse factor for the vegetation of this level is the high incidence of hoarfrost. At this period it occurs with a frequency of from 40% to 50% of the days of the month.

The warm and rainy season receives, under an average temperature of 13.4°C, an amount of rain that corresponds to 50% of the annual amount. Relative humidity rises to an average of 86.4%. Total evaporation is 119.6 mm.

During this three-month period, there occurs, in general, only one day with a clear sky, the cloudiness rising to an average value of 7.9. During this same period there are usually 46 days of fog.

It is during this season that the most violent electric storms occur. The climatic data record an average of 44 days with thunder for this season.

During the 25 years of observation only two snow-falls have been recorded, one in 1918 and another in 1920. It is probable that other snow-falls have occurred, which were not recorded by the observers of the meteorological station.

According to KOEPPEN's system the climate of this level is without doubt of the *Cwb* type, since during the rainiest month of the summer there falls more than ten times more rain than during the driest month, and the temperature of the hottest month is lower than 22°C. *Therefore this climate is one with a mild dry winter, that generally coincides with a climax vegetation with a grassland structure.*

SETZER (1946) and BERNARDES (1952) have considered this climate as belonging to the *Cfb* type, based on the fact, which they considered primordial, that the driest month of the summer receives more than 30 mm of rain. Consequently they contend, although not saying so specifically, that there is no distinct dry season (*vide* KOEPPEN 1948, TREWARTHA 1943).

The observations made during the cold season by the authors, on different occasions, proves that the effect of the dry period upon the vegetation is so harmful that in the grasslands the degree of cover falls from 80% to 10%.

This climate according to DE MARTONNE's system (1948), is of the Mexican type, i.e., a climatic type that occurs in Mexico at 2,200 meters of altitude and also in the high plateaus of Peru, Abyssinia and of the Transvaal.

On the *Lower Highlands,* located in the rain-shadow region, the annual amount of rain is probably smaller than that on the *Upper Highlands,* a fact that is shown by the structure and composition of the vegetation. The climate would probably be similar to the ones that occur at the Alto da Bocaina (1,400 meters) and at Campos do Jordão (1,600 meters), both places located in rain-shadow regions (Table 3). However, here precipitation must be greater than in the above mentioned regions because of the higher altitude. Although the rainfall and temperature during the warm and rainy season are more than sufficient for the germination and the development of the seedlings of the constituents of the previous level woods, *the cold season associated with a period of dryness prevents the permanent establishment of individuals of forest species.* During this period of drought the seedlings of forest species that got established are killed, either by insufficiency of ground water or by hoarfrost.

Only in special habitats, where ground water could be stored during the whole year

and where the action of hoarfrost would not be too strong would the establishment of isolated individuals or colonies of this forest elements be possible. Such habitats are, the base of the boulders; stony, shallow and narrow valleys, and, open and shallow valleys surrounded by low, roundshaped hills.

The greatest part of the area of this level, can, thus, never be occupied by woods, while the present climate lasts. The low content of water in the soil during the dry season, and other unfavourable factors, allow only vegetation composed of therophytes, geophytes and hemicryptophytes (RAUNKIAER, 1934). Even the chamaephytes and nanophanerophytes are of difficult establishment because of hoarfrost action. *Therefore the only admissible structural vegetation types for the well-drained habitats with a mature soil, are grassland and steppe.* In fact, the vegetation that covers these habitats has in certain places the structure of grassland and in others of a steppe.

The vegetation dominated by chamaephytes and nanophanerophytes occur only in well-protected places, free from the action of hoarfrost and of the cold and dry winds, and where also there is a drainage system that allows storage of sufficient ground water to maintain the plants during the dry season.

In the basins with a poor drainage a great amount of water is accumulated during the rainy season and it is sufficient to allow, under the present mean temperature, the formation and maintenance of bogs. The amazing fact is that, in spite of the dry season, these bogs are in their majority sphagnum bogs.

The bogs, where the streams and rivers originate, subjected to continuous drainage from these streams, go completely dry during the unfavourable season, to such an extent that the upper layers of peat crack. However, during the rainy season they recover completely.

Destruction, by oxydation, of the accumulated organic matter, seems to be quite low. *It is probably impeded by an edaphic factor of a chemical nature derived from the special process of rock decomposition* (Segadas-Vianna, 1965).

In spite of this inhibition of the decomposition of the organic matter, the low oxydation associated with a short period favourable to the development of *Sphagnum,* determines the shallowness of the bogs.

Itatiaia Highlands are a true crossroad of migration routes. The plateau's flora is constituted by an assemblage of Andean, Patagonian, Southern Brazilian and Central Brazilian elements.

The number of endemics derived from them is very high, considering the area of the massif. The number of tropical elements is relatively low in comparison with other ones.

The factor that has determined the preservation of these relict elements of past migrations and induced the evolution of new biological taxa *is undoubtedly the special type of climate of the Highlands.* This climate occurs as an island inside the humid tropical climate region. This same reason has prevented and still prevents the occupation of the *Highlands,* that ecologically are an open biome, by tropical elements coming from the lower regions.

CLIMATE OF THE SUMMITS LEVEL

At this level the warm season has a slightly smaller rainfall than the one of the previous level, that is, 5.9 mm less, but during the cold season this difference rises to 33.7 mm.

The annual amount is smaller than the one of the previous level. The difference is 134.5 mm (see Table 3 and fig. 8).

What has been said above, shows that here the dry season is much more individualized and unfavourable than at all the previous levels. It is more than probable that on the ridges that rise from the plateau, for instance at the top of the Agulhas Negras (2,777 meters) and of the Prateleiras (2,539 m), the dry and cold season will differentiate at the same time that the total amount of rainfall decreases. Thus, it seems permissible to say that, in general, on the Serra da Mantiqueira, *the zone of highest condensation is probably located at the level of* 2,000 *meters.*

The climate of this level is also characterized by the constant presence of cold and dry winds of a high intensity, which prevent the establishment of vegetation in the majority of the habitats, including those with a favourable topography.

SUMÁRIO

O objetivo dêste trabalho é o de delimitar a zonação climática e descrever os climas dos diferentes níveis altitudinais do maciço do Itatiaia.

Os dados fornecidos servirão à realização de estudos posteriores referentes ao comportamento da vegetação e ao das diversas comunidades vegetais ocorrentes no maciço. O trabalho sôbre zonação de vegetação, produzido por um dos autores, serviu de base à execução do presente.

Os efeitos dos climas ocorrentes na região, sôbre a vegetação, durante as diversas estações do ano, foram observados pelos autores em diversas excursões, a partir de 1953. Graças a estas observações diretas foi possível completar e melhor interpretar os dados numéricos existentes.

A existência de três estações meteorológicas e de um pôsto pluviométrico permitiu correlacionar os dados climáticos com os andares de vegetação.

A fim de melhor mostrar a zonação climática, foram lançados no mesmo gráfico (veja-se fig. 8), os dados de temperatura e precipitação para cada um dos postos meteorológicos. Os polígonos resultantes, os histogramas, dão perfeita idéia da distribuição altitudinal e comportamento dos climas que caracterizam cada uma das zonas de vegetação. Analisando-se a figura 8 verifica-se que ocorre uma área vaga, entre os histogramas n.º 2 e n.º 3, à qual corresponde a área geométrica que seria ocupada pelos histogramas correspondentes aos climas dos andares *Montanha Média* e *Montanha Superior*, possíveis de serem traçados caso houvesse dados meteorológicos para êstes andares.

Outrossim, pode-se ver através da forma dos histogramas que ocorrem duas estações bem marcadas, — *a estação sêca e fria e a estação chuvosa e quente*. Estas duas estações distinguem-se ainda mais acima de 2.000 metros, onde a estação sêca e fria é de um tipo semi-árido. A posição relativa dos histogramas, por outro lado, mostra que a pluviosidade aumenta regularmente da *Planície* para o *Planalto*, decrescendo no entanto no andar seguinte. A temperatura, como era de esperar, decresce ràpidamente com a altitude.

A figura 8 demonstra claramente a coincidência entre as zonações da vegetação e clima.

O clima do andar *Planície* é, segundo o sistema de KOEPPEN (1948), do tipo *Cwa*, com duas estações bem marcadas: um período quente coincidindo com abundantes chuvas e um período frio associado a uma baixa pluviosidade.

O andar seguinte, *Montanha Inferior*, tem um clima do tipo *Cfb*, isto é, um clima temperado e úmido, com também duas estações bem diferenciadas.

Os climas dos andares *Montanha Média* e *Montanha Superior* devem também ser do tipo *Cfb*, com a estação fria e sêca, provàvelmente, muito mais individualizada e adversa do que nos andares mais inferiores.

O clima do andar *Planalto* é do tipo *Cwb*, sendo que o mês mais sêco, julho, recebe dez e meia vêzes menos chuva que o mês mais chuvoso do ano. A estação fria e sêca é de tal modo individualizada, que pode ser considerada como suficientemente adversa para impedir o estabelecimento de vegetação de tipo florestal, a não ser nos locais bem protegidos. Um outro fator adverso, presente neste andar, é a alta incidência de geadas. Êste tipo de clima é o mesmo que ocorre nos altiplanos do México, Perú, Abissínia e Transvaal.

No último andar, *Cumes*, a estação fria e sêca é ainda mais individualizada e adversa do que no andar precedente. Seu clima caracteriza-se outrossim, pela constante presença de ventos sêcos e frios de alta intensidade.

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